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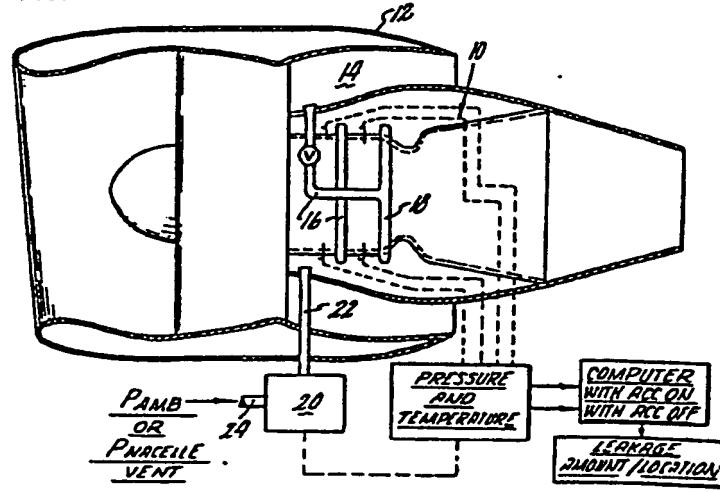
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⑳ Leakage detection and tracking system.

㉑ Leakage monitoring for a nacelle forcing a turbine type power plant powering aircraft is achieved by measuring the pressure inside and outside (or ambient) of the nacelle with

and without a given quantity of flow added inside the nacelle and calculating the leakage by use of the isentropic flow curve. Temperatures may also be sensed at different stations within the nacelle to predict the location of the leakage.

FIG. 1



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## Description

## Leakage Detection and Tracking System

## Technical Field

5 This invention relates to nacelles for aircraft powered by a turbine type power plant and particularly to means for ascertaining and tracking air leakage within the nacelle.

## Background Art

10 As is well known, air leakage from the nacelle occasioned by the many ducts, flanges, joints and connections in the power plant and nacelle create a source of drag to the aircraft, and lost engine work, and consequently a reduction in fuel economy. Obviously, because of the high cost of fuel it becomes abundantly 15 important to be able to ascertain this leakage and compute it in terms of loss of thrust specific fuel consumption (TSFC). This enables the aircraft operator to determine whether it is more expedient to remove the aircraft from service to resolve the leakage problem 20 or to leave the aircraft in service notwithstanding the extra cost resulting from the loss of TSFC. Hence, as is apparent, it would be an advantage in this decision making process to track the leakage from the nacelle and calculate the leakage in terms of loss of TSFC as 25 well as to ascertain the source of the leakage.

To this end, we have found that we can track the leakage from the nacelle of aircraft by measuring the pressure difference between the interior of the nacelle and the exterior of the nacelle (ambient) and compute 30 its value relative to a known quantity of air admitted

into the nacelle. In this manner we can achieve a representative leakage value notwithstanding the fact the leakage area and leakage discharge coefficient of the leaking orifices are unknown. By use of a general 5 or special purpose computer, which is typically available either on ground or in the aircraft, this value can be tracked continuously and either converted in terms of TSFC loss or used as a standard to establish maintenance procedures. By measuring the temperature 10 of the air within the nacelle, it is possible to ascertain whether the leak is from a cool source or a hot source. The temperature data would also have an effect on the TSFC value inasmuch as a leak from a hotter station in the engine gas path has a greater influence 15 on TSFC than does a leak from a lower temperature source.

In certain installations it is contemplated that the temperature and pressure being monitored would be recorded by an on-board flight data recording instrument and this data would be fed to a suitable computer 20 on the ground or within the aircraft to obtain the necessary calculations.

#### Disclosure of Invention

An object of this invention is to provide for aircraft means for tracking the leakage from the nacelle 25 and calculate it in terms of loss of TSFC. A feature of this invention is to measure the pressure differential between air pressure outside the nacelle and within the nacelle during periods of time when a given air flow is added to the nacelle and without the given 30 air flow.

Another feature of this invention is to include a temperature sensor to aid in determining the source of the leakage.

5 Other features and advantages will be apparent from the specification and claims and from the accompanying drawings which illustrate an embodiment of the invention.

#### Brief Description of Drawings

10 Fig. 1 is an illustration, partly in section and partly in schematic, of this invention.

Fig. 2 is a graphical representation of an isentropic flow curve.

#### Best Mode for Carrying Out the Invention

15 While this invention is described in its preferred embodiment being employed with a fan/jet type power plant, as will be apparent to one skilled in the art, it is applicable to any type of power plant that is housed in a nacelle. Also, although the system to be described is conveniently employed where active clearance control (ACC) of the type that flows air on the exterior of the engine case such as that described in 20 U.S. Patent No. 4,069,662 granted to I.H. Redinger, Jr. et al on January 24, 1978 and assigned to the same assignee of this patent application is used, this is 25 not a necessary element to practice this invention.

As noted from Figure 1, a turbine type power plant (fan/jet) 10 is housed in the nacelle generally indicated by reference numeral 12. In the fan type engine as shown, a bypass duct 14 is typically formed by the 30 nacelle for leading fan air overboard. As mentioned above, this embodiment incorporates an active clearance control and reference should be made to the 4,069,662

5 patent, supra, for details thereof. Suffice it to say, fan discharge air is bled from the discharge duct 14 into manifold 16 for feeding spray bars 16 and 18. The spray bars flow the air onto the engine casing to cause  
10 it to shrink in order to control the tip clearance of the rotating blades (compressor and/or turbine). This air flows either rearwardly and discharges with the engine discharge air or leaks through the skin of the nacelle as does other leakages within the nacelle.  
15 These leakage paths are not shown as it is obvious that nacelles in current use are notorious for their leakage problems.

15 The invention serves to measure and track this leakage and compute it in terms of assisting those concerned with maintenance to ascertain when to fix such leakages. Further, the invention contemplates sensing the temperature to ascertain the source of such leakage.

20 In accordance with this invention the pressure differential by a suitable pressure differential transducer generally indicated by reference numeral 20 senses the pressure inside the nacelle by a suitable pressure tap and line 22 and the pressure outside the nacelle by a suitable pressure tap and line 24. The  
25 transducer converts these values to produce an output signal indicative of the differential which is either recorded in a flight data recorder or fed to a computer directly. The computer may be a special or general purpose computer that calculates the value and compares it to  
30 values of pressure differential signals that have to be

obtained when a given air flow was injected into the nacelle.

Obviously, in installations that employ active clearance controls of the type described in U.S. Patent 5 No. 4,069,662 this air may be obtained by flowing the air through the spray bars. The purpose of measuring the pressure differential before and after the known flow injection will be apparent from the following discussion.

10 Since the area of the leakage openings vary considerably and continuously, and since the discharge coefficient is not conveniently known, the calculations presented will account for these unknown by making proportions when a given flow is injected into the 15 nacelle to when this flow is shut off. By making these proportions or ratios, the leakage can be calculated in terms of TSFC with sufficient degree of accuracy to prognosticate when these leakages should be attended to. The best way of understanding the calculations 20 necessary to arrive at these ratios is by considering the following example.

In this example the following symbols will be used.

25  $P$  = pressure  
 $P_c$  = pressure within the nacelle  
 $P_a$  = pressure outside the nacelle or (ambient)  
 $w$  = air flow #/sec  
 $T$  = temperature  
30  $A$  = total leakage area  
 $PSIA$  = pounds per square inch absolute  
 $C_d$  = overboard leakage's discharge coefficient

Assume the following measurements

$$P_c = 4.0 \text{ PSIA}$$

$$P_a = 3.5 \text{ PSIA}$$

5 Calculate the pressure ratio (aircraft instrumentation is suitable to convert the pressure differential signal to the ratio signal).

$$\frac{P_c}{P_a} = \frac{4.0}{3.5} = 1.143$$

From the well known isentropic curve depicted in  
10 Fig. 2

$$\frac{W\sqrt{T}}{APC_D} = .36$$

15 Assume the active clearance control (ACC) when turned on flows  $1.0 \text{#/sec}$  ( $W_{ACC}$ ) (other means can be utilized to flow a given quantity of air).

Assume  $P_c'$  (after ACC is turned on) measures 4.25 PSIA.

Calculate the pressure ratio as follows

$$20 \quad \frac{P_c'}{P_a} = \frac{4.25}{3.5} = 1.214$$

From the isentropic curve of Fig. 2

$$\frac{W'\sqrt{T}}{AP_{c'}} = .41$$

25 Since the ratio of the air flow parameter  $\frac{W\sqrt{T}}{AP}$  is as follows

$$\frac{\frac{W\sqrt{T}}{APC_D}}{\frac{W'\sqrt{T'}}{AP_{c'}}} = \frac{\frac{W\sqrt{T}}{P_c}}{\frac{W'\sqrt{T'}}{P_{c'}}} = \frac{.36}{.41} = .878 = R$$

30 The area value cancels out, along with the discharge coefficient.  $P_c$ ,  $P_{c'}$ ,  $T$ , and  $T'$  are measured.

Since

$$\begin{aligned} W' &= W + (1.0 \text{#/sec}) \\ &= W + W_{\text{ACC}} \end{aligned}$$

Therefore,

$$\begin{aligned} 5 \quad W &= R \left( \frac{W' \sqrt{T'}}{P_c} \right) \frac{P_c}{\sqrt{T}} \\ W &= W_{\text{ACC}} \left[ \left( \frac{P_c \sqrt{T}}{R P_c \sqrt{T'}} \right) - 1 \right]^{-1} \end{aligned}$$

Solving for leakage flow (W) gives

$$\begin{aligned} 10 \quad W &= 1 \left[ \left( \frac{1}{.878} \right) - 1 \right]^{-1} \\ &= 7.197 \text{#/sec} \text{ (ignoring the small pressure} \\ \text{and temperature changes for the purpose of this example).} \end{aligned}$$

15 This value can then be converted into fuel consumption loss.

Assume the temperature sensed was 300°.

20 This compared to the normal 400° temperature (without leakage) would indicate that at say, 35,000 ft. alt. this is below normal and the leak is from the fan air.

25 It should be understood that the invention is not limited to the particular embodiments shown and described herein, but that various changes and modifications may be made without departing from the spirit and scope of this novel concept as defined by the following claims.

## Claims

1. A tracking system to ascertain the amount of air leakage from a nacelle housing an engine powering aircraft, said system comprising means for sensing pressure inside and outside the nacelle in the quiescent stage and in the stage when a given amount of air is fed into the nacelle for providing a first and second signal indicative of the ratio of said pressures in each of said stages, means for calculating the amount of leakage from a known isentropic curve by selecting the air flow parameter for each of said signals and proportioning said values in the static flow equation and means responsive to said calculated value to indicate when said leakage is beyond a given value.  
5
- 10 2. A tracking system as in claim 1 wherein said engine includes an externally mounted active clearance control impinging air of the case of the engine, and means for turning on said active clearance control to provide the stage when a given amount of air is fed into the nacelle.
- 15 3. The method of monitoring the air leakage from a nacelle housing a gas turbine power plant subjected to air leakage comprising the steps of  
20 a. sensing the pressure within said nacelle in both the quiescence state and the state when a predetermined amount of air is ingested into the nacelle for generating a first signal and a second signal;  
25 b. sensing the pressure outside the nacelle for generating a third signal;

- c. calculating the ratio of the first and third signal and the ratio of the second and third signal for obtaining a fourth signal and a fifth signal;
- 5 d. compute the flow parameters from the isentropic relationship of the compressible fluid flowing into and out of the nacelle from a preselected isentropic flow curve suited for the type of flow encountered in a nacelle from the ratio calculated in the step immediately above; and
- 10 e. calculate from the static flow equation the amount of leakage that is present in the nacelle by proportioning the fourth signal and fifth signal.
- 15 4. The method as in claim 3 including an active clearance control externally of the engine and the step of turning on said active clearance control to ingest a predetermined amount of air in said nacelle.
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